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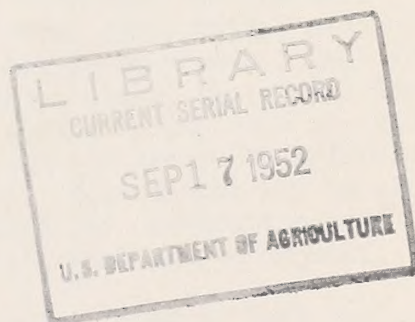


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MISCELLANEOUS REPORT NO. 20

LOW TEMPERATURE SEED STORAGE FOR WESTERN CONIFERS

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FOREST SERVICE  
Lake States Forest Experiment Station





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If all forest tree species produced good seed crops every year, we would have no long-time seed storage problems. Unfortunately, most of the coniferous species commonly used in reforestation bear good seed crops only at intervals of several years. For example, the more important western conifers can be depended on for good seed crops only every 3 to 7 years (table 1). To conduct regular reforestation programs on a large scale, therefore, we have the alternatives of nursery production fluctuating with annual seed production or collecting enough seed in the good years to supply the necessary stock for 2 to 6 years' production. Administratively the latter is preferable; so these extra quantities of seed must be stored in such a manner that the maximum viability is retained.

CONDITIONS REQUIRED FOR LONG-TIME SEED STORAGE

As coniferous tree seeds ripen, they undergo certain characteristic physical and chemical changes. Physically they usually change in color and lose moisture. Chemical composition usually is altered as follows:

"Soluble organic compounds such as simple sugars, fatty acids, and amino acids are gradually converted into more complex carbohydrates, fats and oils, and proteins" (5). In the course of germination, the biochemical changes usually are the reverse of those occurring during seed ripening. These changes cannot take place unless the seed has access to moisture, favorable temperatures, and sufficient oxygen. Here is the key to successful storage practices. The conditions required for germination must be withheld from the seed which, at the same time, must not be injured.

Seeds of some trees, particularly the nut species, must be kept moist or they lose their viability. Others, which have hard, impermeable seed coats, such as many of the legumes, may be kept for many years without special precautions. Seed of the majority of our tree species, however - and this includes most of the conifers - retain their viability best under dry, cold storage.

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<sup>1/</sup> Prepared for Third Biennial Forest Tree Nurseryman's Meeting held on August 12 and 13, 1952, at British Columbia Forest Service, Green Timbers Nursery, near New Westminster, B. C.

<sup>2/</sup> Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota, University Farm, St. Paul 1, Minnesota.





Table 1.--Seed crop intervals for some western conifers

Species	Seed-year frequency	
	Good crops	Light crops
	<u>Years</u>	<u>Years</u>
Alaska-cedar ( <i>Chamaecyparis nootkatensis</i> )	Occasional	Most intervening
Port-Orford-cedar ( <i>C. lawsoniana</i> )	4-5	do
Western redcedar ( <i>Thuja plicata</i> )	2-3+	Intervening
Douglas-fir ( <i>Pseudotsuga taxifolia</i> )	3-7	do
California red fir ( <i>Abies magnifica</i> )	2-3	do
Grand fir ( <i>A. grandis</i> )	2-3	do
Noble fir ( <i>A. procera</i> )	Infrequent	do
Pacific silver fir ( <i>A. amabilis</i> )	2-3	do
White fir ( <i>A. concolor</i> )	2-4	do
Western hemlock ( <i>Tsuga heterophylla</i> )	2-5	do
Western larch ( <i>Larix occidentalis</i> )	5-6	Most intervening
Jeffrey pine ( <i>Pinus jeffreyi</i> )	2-4	1-3
Lodgepole pine ( <i>P. contorta</i> var. <i>latifolia</i> )	1-3	Intervening
Ponderosa pine ( <i>P. ponderosa</i> )	2-5	2-3
Sugar pine ( <i>P. lambertiana</i> )	3-5	Most intervening
Western white pine ( <i>P. monticola</i> )	4-6	3
Redwood ( <i>Sequoia sempervirens</i> )	1+	Intervening
Engelmann spruce ( <i>Picea engelmanni</i> )	2-3	do
Sitka spruce ( <i>P. sitchensis</i> )	3-4	do





## METHODS OF COLD STORAGE

### Moisture Content

Before storage, seeds of most American conifers should be dried down to a moisture content of 10 percent or less of oven-dry weight. Kiln-dried seeds or those which have been air-dried in dry climates, as in the Rocky Mountain region, ordinarily have a moisture content low enough for storage. Any additional drying needed should be rapid enough to prevent heating or molding, yet not so rapid or at such high temperatures as to injure the seeds.

The seeds must not only be put into storage at low moisture contents, but they must be prevented from regaining moisture in storage. This requires either that the seeds be held in sealed containers or that the entire storage chamber be kept at suitably low relative humidities. Normally it is more practical to use sealed containers.

### Temperature

Experimental evidence has shown that temperatures just above freezing slow down the life processes within the seed and yet maintain its viability. Temperatures between 33° and 50°F. have been found satisfactory for many species. As a rule, constant temperatures have proved better than those which fluctuate more than a few degrees. Seeds of many species can be stored satisfactorily for a few years in cool cellars or special insulated storage sheds in which temperatures show a gradual rise and decline with the seasons, but viability is retained longer and more fully in controlled cold storage.

### Oxygen

Pine seeds (loblolly, longleaf, slash, and red) stored in a partial vacuum kept better than those in ordinary sealed containers at room temperatures, but there was little difference when storage was at low temperatures (1). Normally it is easier to provide low temperatures than partial vacuums for storing large amounts of seed.

### Containers

The type of seed cans with screw-tops used by the U. S. Forest Service in several regions has proved quite suitable for storing seeds for several years, so long as storage conditions were otherwise favorable. Small lots can be kept in jars or similar containers sealed with paraffin.

## STORAGE OF SOME WESTERN CONIFER SEEDS

Results of cold storage have been published for only some 10 of the more important western conifers (table 2). Information is also available for 9 less important pines (whitebark, bristlecone, knobcone, foxtail, shore, Monterey, Santa Cruz Island, and Torrey pines) (2). This information is quite consistent in indicating that viability of these western conifer seeds can be maintained with little or no loss for 5 to 10 years if the seeds are held in sealed storage at temperatures of about 40°F.

# THEORY OF THE EARTH

## CHAPTER I

Before entering upon the study of the theory of the earth, it is necessary to have a clear idea of the scope and limits of the subject. The theory of the earth is a branch of geology, and it deals with the origin and development of the earth and its various parts. It is a science which seeks to explain the causes of the various geological phenomena which we observe in nature.

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## CHAPTER II

The earth is a planet which is composed of various parts. The parts of the earth are the crust, the mantle, and the core. The crust is the outermost part of the earth, and it is composed of various rocks and minerals. The mantle is the part of the earth which lies between the crust and the core, and it is composed of various rocks and minerals. The core is the innermost part of the earth, and it is composed of various rocks and minerals.

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Table 2.--Some results with cold storage of western conifer seeds

Species	Storage		Viability	Data source
	Temperature	Duration	reduction	
	<u>Degrees F.</u>	<u>Years</u>	<u>Percent</u>	
Douglas-fir	40	4+	0	( <u>5</u> )
Grand fir	40	11	50	( <u>5</u> )
Noble fir	36-39	5+	Little	( <u>5</u> )
Jeffrey pine	40	8+	0	( <u>2</u> ), ( <u>5</u> )
Lodgepole pine	40	9+	Little	( <u>2</u> ), ( <u>5</u> )
Ponderosa pine	40	11+	0	( <u>2</u> ), ( <u>5</u> )
	5 to 23	4+	0	( <u>1</u> )
Sugar pine	40	11+	60	( <u>2</u> ), ( <u>5</u> )
Western white pine	40	8+	0	( <u>2</u> )
Redwood	26-30	1-10	50+	( <u>5</u> )
Engelmann spruce	40-60	5	20	( <u>5</u> )





Douglas-fir seed has retained full viability for at least 4 years when stored at 40°F. in sealed containers. It seems reasonable that seed of this species could be held at least 3 more years without serious deterioration. Supplies could, therefore, be stored satisfactorily over the maximum period to be expected between good seed crops.

Seed of the true firs can be held little more than one year under ordinary storage. However, seed of grand fir still retained 50 percent of its initial viability after 11 years' sealed storage at 40°F. and seed of noble fir had lost very little germinability after 5 years' storage at 36-39°F. White fir seed apparently is more perishable; samples have deteriorated after 4 years' sealed, cold storage. There seems to be no good reason why seed of California red fir, Pacific silver fir, and other western true firs could not be stored satisfactorily in the same manner for the 3 to 4 years which may elapse between good seed crops.

The more important western pines all produce good seed crops at intervals not exceeding 6 years. Studies show that seed of all these species can be kept at 40°F. for several years with little or no impairment of viability. Jeffrey pine and western white pine seed have been stored for over 8 years, lodgepole pine for over 9 years,<sup>3/</sup> and ponderosa pine for over 11 years with full viability. After 11½ years' storage at 40°F., sugar pine seed retained 40 percent of its initial viability; some germination was still obtained after 14½ years' cold storage (2). As a matter of fact, seed of Pinus ponderosa var. scopulorum was still viable after 23 years' storage in a cool cellar in a dry climate.

Redwood seed has been stored up to 10 years at 26° to 30°F. with a loss of about 50 percent of its initial viability. Because of frequent good seed crops, there is little need ordinarily for storing redwood seed more than one year. Seed of the related giant sequoia apparently keeps better. Reports are that its seed has kept for 8 to 24 years with a moderate loss in viability.

Engelmann spruce seed stored in sealed containers in a cool cellar (temperature range probably about 40° to 70°F.) retained its viability unimpaired for 3 years and had lost only about 20 percent of it in 5 years (5). In view of this and the fact that seed of white and red spruces have kept well for at least 10 years at temperatures near 40°F., it seems probable that Engelmann, Sitka, and other western spruce seeds can be held satisfactorily in cold sealed storage for at least 5 to 10 years, which usually is all that is necessary.

#### Some Species For Which Information Is Lacking

There are several other important western conifers for which information on cold storage of seed is lacking. For several of them, however, we can make some assumptions based on storage behavior of seed of related species.

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<sup>3/</sup> There may be little need to store this seed because of the supply normally present in serotinous cones.





Storage information is lacking for seed of Port-Orford-cedar and Alaska-cedar, but seed of the closely related southern white-cedar has kept well for one year when stored naturally in the peaty forest floor. Seeds of some species in the closely related genus Cupressus have retained considerable viability for 10 years when stored unsealed at temperatures fluctuating from 40° to 90°F. (5). It is reasonable to expect, then, that Chamaecyparis seeds can be held for several years in sealed storage at about 40°F. with good retention of viability.

Western redcedar seed maintained fair viability for 2 years when stored in sealed containers at ordinary room temperatures. However, seed of northern white-cedar (in the same genus) kept well for 5 years in air-tight containers at 35° to 40°F., although the seed deteriorates rapidly at higher temperatures or when exposed to moisture (5). Western redcedar seed should keep well for at least 3 to 5 years in air-tight containers stored at temperatures between freezing and 40°F.

Western hemlock seed stored at room temperature for 2 or 3 years in sealed containers lost little germinative capacity. One lot of eastern hemlock seed germinated well after 4 years' storage at 41°F. in sealed containers but had deteriorated after 6 years' storage (5). Presumably western hemlock seed could be stored satisfactorily at slightly above freezing temperatures for the 5 years which might occur between good crops.

Western larch seed has been kept for 1 or 2 years in sealed containers at room temperatures with an annual loss of about 6 percent of its germinative capacity (5). European larch seed lost no viability in 4 years' sealed storage at 32° to 50°F. (5). There should be a good possibility, therefore, that western larch seed could be held satisfactorily in sealed storage at about 40°F. for the 5 or 6 years which might be required between good crops.

#### SOME PRACTICAL CONSIDERATIONS

Evidence is consistent that seeds of several western conifers can be stored satisfactorily for 5 or more years at low moisture contents in sealed containers at temperatures near 40°F. On large operations involving seeds of species which produce good seed crops not oftener than 3 years, it may pay to install cold storage facilities.

In some localities commercial cold storage facilities are available. Such establishments usually maintain temperatures below the 40°F. found satisfactory for many tree seeds. In fact, temperatures usually are held below freezing. It is important to know, therefore, whether tree seeds can be stored safely at sub-freezing temperatures.

Fortunately there are tests on seed of a few coniferous species which were stored at temperatures between 5° and 23°F. These tests indicate that seed of ponderosa, red, loblolly, longleaf, slash, and shortleaf pines and white





and Norway spruces kept well for 4 to 7 years at sub-freezing temperatures (1). These seeds were stored at moisture contents between 0 and 6 percent, many of them at less than 1 percent. If the seeds are sufficiently dry, they apparently can withstand sub-freezing temperatures for several years without injury. Possibilities seem good, then, that many commercial cold storage facilities can be used to advantage in storing conifer seeds.

It should be stressed that conifer seeds scheduled for prolonged cold storage should contain less than 7 percent moisture. Tests at the Lake States Forest Experiment Station with red pine and eastern white pine have demonstrated this (3, 4). With both species lower moisture contents have proven better. Usually conifer seeds which are extracted in forced-air kilns and often in convection kilns have moisture contents low enough for long storage. It is desirable also that the moisture content of the seed be kept low throughout the storage period. Even in sealed jars there may be a build-up of moisture, as shown in the eastern white pine tests, supposedly from leakage around deteriorating rubber rings. For example, seed with an initial moisture content of 5.6 percent 10 years later contained 11.2 percent moisture (4).

#### MORE KNOWLEDGE NEEDED

This brief summary of knowledge on the cold storage of western conifer seeds points out not only some promising leads but also a conspicuous lack of knowledge for many species. Some information is available on the effects of cold storage of seed for only about half of the more important western conifers. Many of these need more study to clarify the most desirable moisture contents and temperatures for long-time storage. Comprehensive seed storage studies are needed also for those species not yet investigated. Only for ponderosa pine is there information on the effects of seed storage below freezing temperatures. This should be studied further for all the important species.

#### SUMMARY

Most western conifers bear good seed crops only every 3 to 7 years. For regular, large-scale reforestation projects it is necessary, therefore, that seeds of most species be stored for 2 to 6 years. Information indicates that seed of the following 10 species can be kept at about 40°F. in sealed containers for 5 to 10 years with little loss in viability: Douglas-fir, grand fir, noble fir, Jeffrey pine, lodgepole pine, ponderosa pine, sugar pine, western white pine, redwood, Engelmann spruce; and 9 less important pines. White fir seed can be held for 3 or 4 years. Seeds of several other important western conifers probably can be stored in the same manner because of their similarity to other species for which information is known. These include: Alaska-cedar, Port-Orford-cedar, western redcedar, California red fir, Pacific silver fir, western hemlock, western larch, giant sequoia, and Sitka spruce.





Many commercial cold storage plants are run at temperatures below freezing. Studies have shown that seed of ponderosa pine and some other pines and spruces can be stored safely at such temperatures for several years at low moisture contents. Probably other species can also be stored in the same manner.

It is important that seed contain less than 7 percent moisture when placed in long-time storage. The containers should be sealed so that the moisture content cannot increase over the storage period.

Research has given promising leads as to the requirements for long-time seed storage for several species. However, more information is needed for many of these species, and those species not yet studied should be the subjects of research. There is need to investigate especially the effects of sub-freezing temperatures on the viability of seeds of all important species.

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